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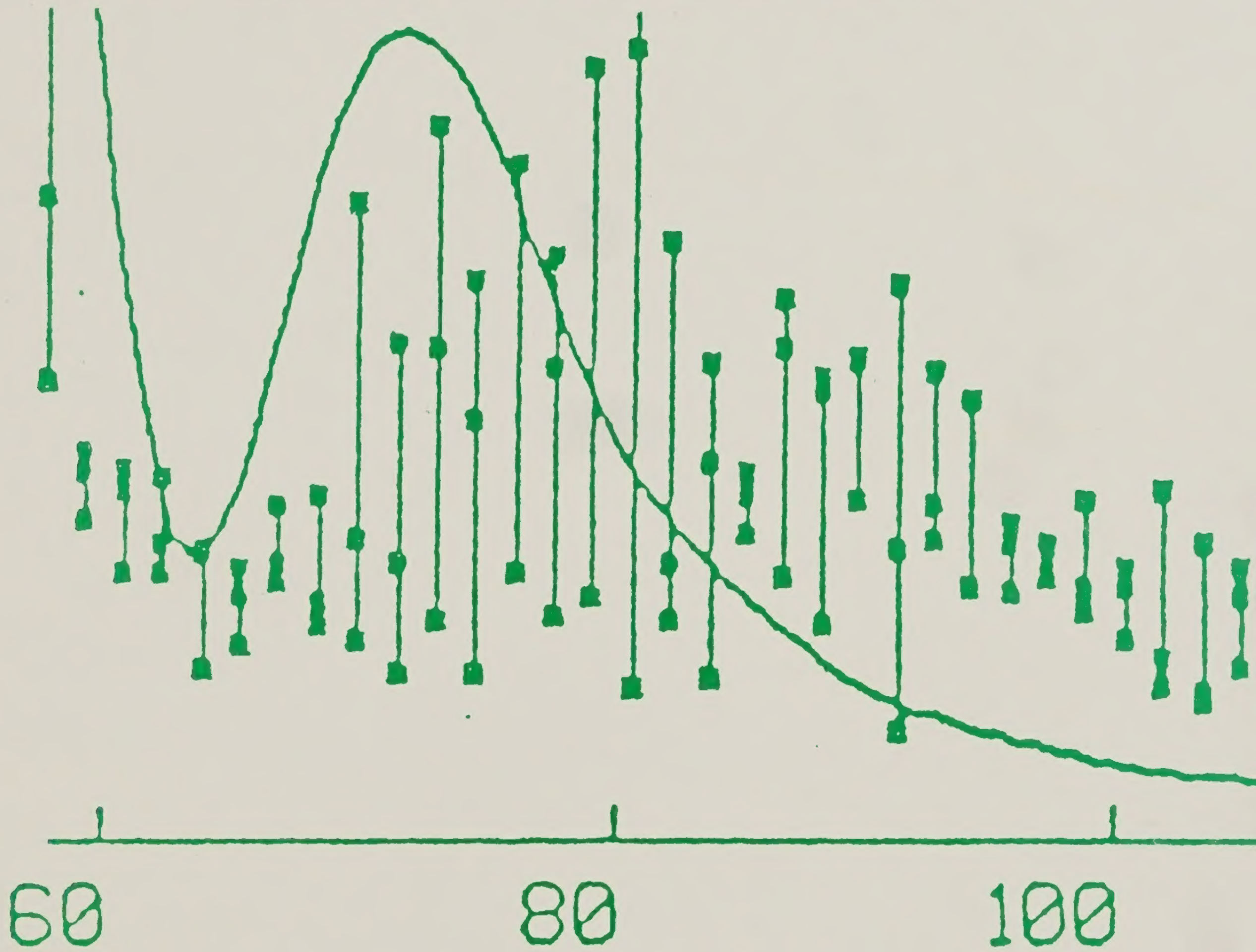
Forest Service

Technology and Development Program

Missoula, MT

Final Report

AGDISP Comparisons With The Mission Swath Width Characterization Studies



May 1988
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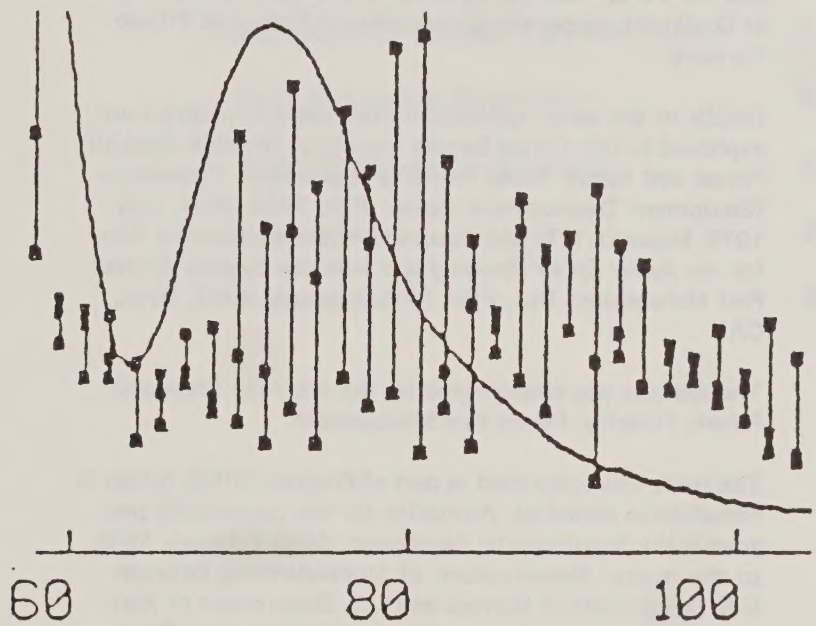

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May 1988

(This work was done under contract 53-0343-7-00952)

Foreword

This report is published as a part of the USDA Forest Service program to improve aerial application of pesticides, specifically by using pesticides and delivery systems tailored to the forest environment. The program is conducted jointly by the Technology and Development Center, Missoula, MT, and the Forest Pest Management Staff, Washington Office at Davis, CA, under the sponsorship of State and Private Forestry.

Details of the aerial application improvement program are explained in two Forest Service reports: *A Problem Analysis: Forest and Range Aerial Pesticide Application Technology* (Equipment Development Center Rpt. 7934 2804, July 1979, Missoula, MT) and *Recommended Development Plan for An Aerial Spray Planning and Analysis System* (Forest Pest Management Rpt. FPM 82-2, February 1982, Davis, CA).

The analysis was cosponsored by the NE Area State and Private Forestry, Forest Pest Management.

The study was conducted as part of Program WIND (winds in nonuniform domains). Authority for the cooperative program is the Supplemental Agreement, dated February 1985, to the master Memorandum of Understanding Between U.S. Department of Defense and U.S. Department of Agriculture Relative to Cooperation with Respect to Food, Agriculture, and Other Research of Mutual Interest.

Pesticide Precautionary Statement

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

Caution: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Contents

Executive Summary

The swath width characterization studies conducted in Mission, Texas, by the United States Department of Agriculture Forest Service, Forest Pest Management, and Forest Pest Research; APHIS-GM Methods Development Laboratory and Aircraft Operations; and the Department of Entomology Pennsylvania State University, form a significant data base with which to compare ground deposition predictions with the computer program AGDISP.

AGDISP predicts the motion of aerially released material, including the mean position of the material and the position variance about the mean as a result of turbulent fluctuations. AGDISP is based on a Lagrangian formulation of the released material equations of motion, and includes simplified models for aircraft wake and ambient turbulence effects. To this point AGDISP predictions have been compared with data in the following tests:

1. U.S. Army aircraft small-particle spraying tests at Dugway Proving Grounds in 1974 with a DC-7B;

2. Forest Service tests from the Withlacoochee seed orchard in 1980 with a Stearman biplane and Hughes 500C helicopter;

3. NASA/Langley Wallops Island study in 1981 with glass beads from an Ayres Thrush aircraft;

4. Program WIND Phase I test results from the Chico almond orchard tests in 1985 with an AgCat biplane and Hiller 12E helicopter; and

5. Program WIND Phase III test results from the Red Bluff forest tests in 1986 with a C-130 and Bell Ranger 206 helicopter.

While AGDISP comparisons were quite favorable with the Wallops Island tests, those tests lacked evaporative effects and were restricted to a fixed-wing aircraft. The other four tests included helicopter studies but were, for the most interesting and numerous cases, conducted within a forest canopy. While a canopy deposition model is currently under development for the AGDISP code, the lack of a sufficient experimental data base without canopy still leaves a gap in data comparison with the AGDISP model. That gap is closed with the Mission data set.

Results indicate the following:

1. Interpretation of the measured surface wind and temperature at the test site indicates that in all Mission runs, crosswind velocity and evaporative effects were significant. The AGDISP program includes models for these effects and was therefore able to accurately predict the measured ground deposition data.

2. AGDISP calculations for each Mission run were made with the eight particle size-classes containing the most material volume. These size-classes were selected from a wind-tunnel experiment that maintained the same spray nozzle configuration as used in the Mission runs. However, AGDISP models had to be utilized to account for the evaporation of these size-classes from the aircraft to the ground collectors.

3. The ground deposition data was collected on cards elevated just off the surface. Since the current version of AGDISP assumes unity for collection efficiency, the collection efficiency had to be inferred from the washoff data, and subsequently applied to the image analysis data. A one-to-one comparison of AGDISP prediction with the Mission data set could not be made without first correcting the data for evaporative effects and collection efficiency.

4. The material released from the nozzle contained an emulsifier that inhibited the evaporation of the water base. The volatility fraction of the released material in the Mission data set had to be inferred from the data.

5. There was therefore some ambiguity in the magnitude of the ground deposition (about 20 percent) when comparing the predicted and measured levels. However, comparisons with data cannot dispute the excellent agreement of the AGDISP predictions with the shape and location of the Mission ground deposition data. Overall, AGDISP comparisons with the Mission data set significantly enhance confidence with the computer program in predicting ground deposition accurately.

Introduction

For the last 15 years the United States Department of Agriculture Forest Service and the United States Army have been pursuing the development of computer codes to predict the deposition distribution of aerially released material. The two current codes under review are AGDISP *(Teske, Ref. 1)* and FSCBG *(Dumbauld, et al., Ref. 2)*.

AGDISP is based on a Lagrangian formulation of the released material equations of motion, and includes simplified models for aircraft wake and ambient turbulence effects. FSCBG considers multiple aircraft passes as Gaussian line sources of released material. The FSCBG model has had extensive comparisons with data *(Boyle, et al., Ref. 3; Barry, et al., Ref. 4; and Rafferty, et al., Ref. 5)*. AGDISP data comparisons have been made by Morris, *et al. (Ref. 6)*, and for the above data sets and applicable Program WIND results *(Keetch, Ref. 7 and 8)* by Teske *(Ref. 9)*.

These data sets have, for the most part, test conditions that make comparison with AGDISP predictions difficult. The Morris data was restricted to solid glass beads that jammed the exit ports of the nozzles and made determination of the flow rate impossible. The Boyle data were for material volume median diameters less than 100 microns, which precluded a complete AGDISP simulation because of solution stepsize constraints. (The constraints are currently being removed from the program). And the Barry, Raffferty, and Keetch data were, for the most part, collected in forest canopies, for which an AGDISP model is under development.

The Mission swath width studies were conducted between March 7 and 12, 1987, in an attempt to characterize spray patterns for a specific aircraft. In addition, the Mission studies were designed to measure and/or collect sufficient data to permit a quantitative comparison of the ground deposition results with AGDISP predictions.

The Summary of Mission Test Conditions in this report briefly summarizes the Mission test conditions and spray characterization. Data Reduction Algorithm discusses the data reduction algorithm, and points out issues in data comparison. AGDISP Model Comparisons contains the 15 sets of applicable tests (out of 21) and all auxiliary data comparisons. The last section of the report discusses conclusions.

Summary of Mission Test Conditions

The Mission, Texas, tests were conducted by the United States Department of Agriculture Forest Service, Forest Pest Management, and Forest Pest Research; APHIS–GM Methods Development Laboratory and Aircraft Operations; and the Department of Entomology, Pennsylvania State University, to characterize the swath width of a Cessna 188 AgTruck typically used in their spray operations in northeastern United States *(Reardon, Ref. 10)*. Sufficient data were taken to initiate AGDISP predictions of these runs. The test site is shown schematically in Figure 1. Twenty-one runs were conducted.

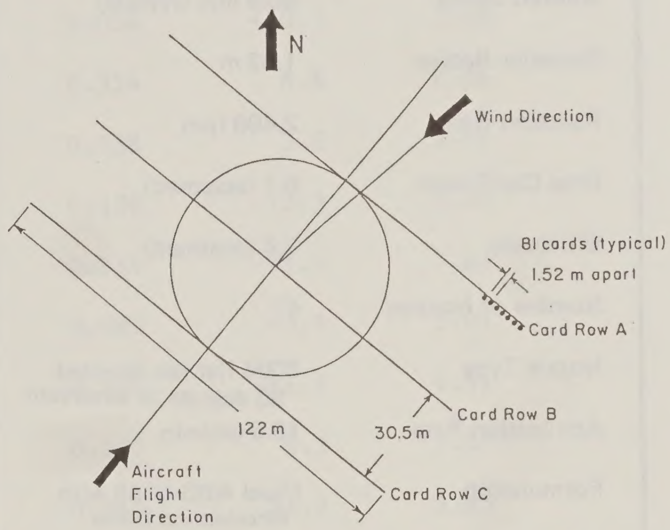

Figure 1.—Test site for the Mission, Texas, swath width characterization tests.

During all tests, wind direction and speed were recorded in 10-second intervals from anemometers located on towers off the schematic to the right in Figure 1. Anemometers were located at 0.5, 2.5, 5, 10 and 15 meter heights above the surface. Additionally, the wet bulb and dry bulb temperatures were recorded at the 15 meter height. Dry bulb temperatures were also recorded at the other heights, along with relative humidity and barometric pressure. Deposition collection was made 0.15 meters above the surface onto KromeKote cards treated for both subsequent image analysis and fluorometric washoff. Rhodamine tracer was added to the spray tank mix to afford volumetric determination. All applicable test data, suitably reduced, were provided to Continuum Dynamics, Inc. by Pennsylvania State University *(Meirzejewski, et al., Ref. 11)*. Spraying characteristics are summarized in Table 1.

Table 1. — Summary of Spraying Characteristics

Aircraft Type	Cessna 188 AgTruck
Semispan	6.37 m
Planform Area	19.05 m^2
Aircraft Weight	13,860 N (typical)
Aircraft Altitude	15.55 m (mean)
Aircraft Speed	50.9 m/s (typical)
Propeller Radius	1.02 m
Rotation Rate	2,400 rpm
Drag Coefficient	0.1 (assumed)
Efficiency	0.8 (assumed)
Number of Nozzles	47
Nozzle Type	8004 flat fan directed 90 degrees to airstream
Application Rate	18.2 gal/min
Formulation	Dipel ABG-6158 with Rhodamine tracer
Volatility Fraction	54 percent (deduced from data)
Analysis Techniques	Image Analysis Fluorometric Wash-Off

A typical run consisted of observing the mean wind direction and aligning three rows of 81 cards each perpendicular to the perceived wind. The aircraft would then fly perpendicular to the card rows. After deposition was completed, or the spray had drifted off the card grid, the cards were collected and the next run was conducted. Table 2 summarizes the run test conditions.

The surface wind always shifted away from the flight path. Therefore, a slight (and in some cases substantial) crosswind existed during each run. All runs (except runs 5 through 8) were conducted in the early morning to give a more stable temperature layer.

Measurements were made of the aircraft weight, altitude, and speed, and of the engine characteristics. Nozzle placement was measured in the field and particle size classes were suggested from a wind-tunnel test of an 8004 flat fan nozzle simulating the Mission operating conditions *(Yates and Steinke, Ref. 12)* (Table 3). Resources such as Hardy *(Ref. 13)* were used to complete AGDISP input specification. AGDISP calculations were made for all available Mission runs and comparisons were made with the experimental ground depositions.

Table 2. — Summary of Run Test Conditions

Run	Date	Time	Wind Speed at 10 m (m/s)	Roughness Height (m)	Turbulence Level (m^2/s^2)	Relative Wind Direction (degrees)	Wet Bulb Depression (degrees C)
1	03/07	09:54	3.71	0.0045	0.196	32.1	2.25
2	03/08	07:27	1.86	0.8148	0.467	16.1	1.09
3	03/08	08:02	0.63	0.4209	0.033	25.2	1.13
4	03/08	09:25	1.68	0.0130	0.054	-10.3	3.58
5	03/08	17:01	3.82	0.0274	0.354	8.6	7.66
6	03/08	17:26	3.33	0.0188	0.238	3.3	7.47
7	03/08	17:48	2.38	0.0179	0.120	-10.3	7.32
8	03/08	18:16	3.09	0.0627	0.314	-38.7	7.26
9	03/09	08:25	5.87	0.0147	0.685	-3.6	2.01
10	03/10	06:58	3.44	0.0336	0.308	-11.1	1.51
11	03/10	07:20	2.64	0.0909	0.267	6.2	1.22
12	03/10	07:41	3.37	0.0231	0.260	11.2	1.65
13	03/10	08:15	4.02	0.0129	0.308	21.2	2.35
14	03/10	09:13	6.11	0.0134	0.721	1.3	3.65
15	03/12	07:12	3.84	0.2796	0.974	6.7	0.85
16	03/12	07:47	4.49	0.0470	0.592	23.9	0.99
17	03/12	08:33	4.66	0.0232	0.499	2.8	1.13
18	03/12	09:20	3.80	0.0125	0.273	-7.4	1.72
19	03/12	09:55	3.78	0.0111	0.261	-4.8	2.53
20	03/12	10:47	2.41	0.0095	0.101	-16.2	2.91
21	03/12	11:25	1.90	0.0111	0.066	3.0	3.09

Table 3. — Summary of Particle Size Classifications

Particle Size (microns)	Number Density (percent)	Volume (percent)	Mean Diameter (microns)
0 - 56	53.40	3.84	
56 - 89	19.34	8.40	73.7
89 - 122	13.60	18.04	106.4
122 - 154	7.89	23.60	138.6
154 - 187	3.81	21.57	171.0
187 - 220	1.32	12.66	203.9
220 - 252	0.41	6.13	236.4
252 - 284	0.14	3.06	268.3
284 - 318	0.05	1.59	301.3
318 - 351	0.01	0.61	
351 - 382	0.01	0.35	
382 - 414	0.00	0.07	
414 - 447	0.00	0.03	
447 - 479	0.00	0.06	

Data Reduction Algorithm

Table 1 summarizes the Mission spraying characteristics. Two values from this table require additional explanation:

1. Although the aircraft altitude was recorded for each run, the reliability of the data were questioned by Mierzejewski (*private communication*), and the average altitude was used for all AGDISP runs.

2. The volatility fraction shown in Table 1 was determined by a technique described later in this section.

Table 2 summarizes all run test conditions. Data reduction for the atmospheric data proceeded as follows. All applicable anemometer direction data were averaged regardless of sensor height to arrive at an average wind direction for a run. This wind direction was then compared with the recorded flight path of the aircraft to obtain the column in Table 2 marked *Relative Wind Direction*. All applicable wind speed data were used to curve fit the surface velocity profile to a neutral logarithmic profile by least squares. This approach permitted the recovery of the average *Wind Speed at 10 meters* and the *Roughness Height* as given in Table 2. A consistent *Turbulence Level* was obtained by using an equation found in Teske (*Ref. 1*).

The *Wet Bulb Temperature Depression* was found by averaging all applicable data obtained by subtracting the recorded wet bulb temperature from the recorded dry bulb temperature at 15 meters. Run 1 did not have the required temperature data. In this case, the relative humidity and dry bulb temperature at 10 meters were averaged, then used with an engineering table to generate the wet bulb temperature depression (*Weast, Ref. 14*).

Table 3 summarizes the particle size-classes suggested by the experiment of Yates and Steinke (*Ref. 12*) for the specific nozzle, spray material, and operating conditions in the Mission runs. The smallest particle sizes (0 to 56 microns) generate over half the number density but contribute less than 4 percent of the volume. Since the solution algorithm speed in the AGDISP program is strongly dependent on the material size, we believed it would be computationally prudent to discard the 0 to 56 micron contribution. Since particle sizes below 40 microns were also difficult to count with the image analysis technique (*Mierzejewski, private communication*), the smallest particle size selected by Yates and Steinke was thus discarded. The larger sizes (above 318 microns) were discarded because their volume contributions were each less than 2 percent.

This procedure left eight particle size-classes to discretize the Mission spray using AGDISP. The approach taken was to assume a mean particle diameter to represent each size-class, run a separate AGDISP prediction for this size, then multiply the resultant ground deposition determined by AGDISP by the Table 3 volume percentages suggested by the Yates and Steinke tunnel tests. If all of the material released from the nozzles hit the surface and did not evaporate or drift off the card rows, an integral of the predicted ground deposition would recover the release rate of 18.2 gal/min. Since drift did indeed occur, especially for the smaller particles, and evaporation was important in all runs considered, the predicted deposition was always less than the spray release rate.

The initial mean particle diameters in all size classes considered are also given in Table 3, and were obtained from the formula

$$d = \left[\frac{d_{max}^4 - d_{min}^4}{4(d_{max} - d_{min})} \right]^{1/3} \tag{1}$$

suggested by Dumbauld (*private communication*) consistent with FSCBG, and found in Herdan (*Ref. 15*).

Prediction of the ground deposition by AGDISP was then straightforward. However, the correct interpretation of the data lead to additional assumptions and procedure. The answers to four questions had to be inferred from the data:

1. The emulsifier present in the released material inhibied evaporation of the water base. What was the volatility of the released material, or, what was the fraction of material that did not evaporate due to the wet bulb temperature depression?

2. The tracer present in the released material did not evaporate, but was carried suspended within material that evaporated. How might the tracer deposition be predicted by AGDISP and compared with the washoff card data?

3. The Yates and Steinke tunnel results gave a good indication of the initial particle size distribution. These particles subsequently evaporated and drifted before depositing on the image analysis cards. Since the data were collected in 20 micron incremental bins (20—40 microns, 49—60 microns, etc.), how should the deposited data be interpreted to best represent the ground deposition of the released material?

4. What was the effect of the deposition cards elevated 0.15 meters off the surface?

All these questions were answered by taking advantage of the predicted results and the evaporation model present in AGDISP. We agreed that the comparison should be between the predicted ground deposition and the measured deposition corrected for collection efficiency. Since the AGDISP code does not currently model collection efficiency, some of the Mission data were used to infer the collection efficiency on the cards.

By predicting the amount of tracer that should have deposited on the cards and comparing that prediction with the tracer amount obtained by the washoff technique, we could form the average collection efficiency for any Mission run. The image analysis data on the other half of the cards gave the number of drops in any experimental particle size bin. By using a procedure that incorporated the AGDISP evaporation model, the limits of each particle size class could be inferred at the ground (the size-classes would evaporate downward). The total number of particles in each size-class could then be multiplied by the evaporated mean particle volume (determined with Equation 1) to obtain the volume on each card for each size class. By assuming that the collection efficiency for the tracer was the same as for the drops (the drops carried the tracer to the ground), the total number of drops and volume of material could be divided by the collection efficiency to obtain the corrected ground deposition data. These corrected data were then compared with AGDISP prediction.

The washoff data provided the additional information needed to determine the volatility fraction (given in Table 1) and the collection efficiency for each Mission run. An integral of the tracer along the surface must equal the amount of tracer released at the nozzles minus the amount drifting off the card rows. The amount drifting could be estimated by the AGDISP solution for each particle size for each run. Each particle size was assumed to carry its same volume fraction of tracer. For example, if the 301.3 micron diameter particles all reached the surface (which they did in all runs), then the amount of tracer that must be on the surface from this particle size class is the 301.3 micron diameter volume fraction (Table 3) of 1.59 percent. Even though the material has evaporated, the tracer has not. There is more tracer per unit material at the surface than at the nozzles because of evaporation.

Summing the volumes in the eight particle sizes from the AGDISP predictions and comparing with an integral of the tracer washoff yields the collection efficiency. These results are shown in Figure 2, where collection efficiency is plotted against wet bulb temperature depression.

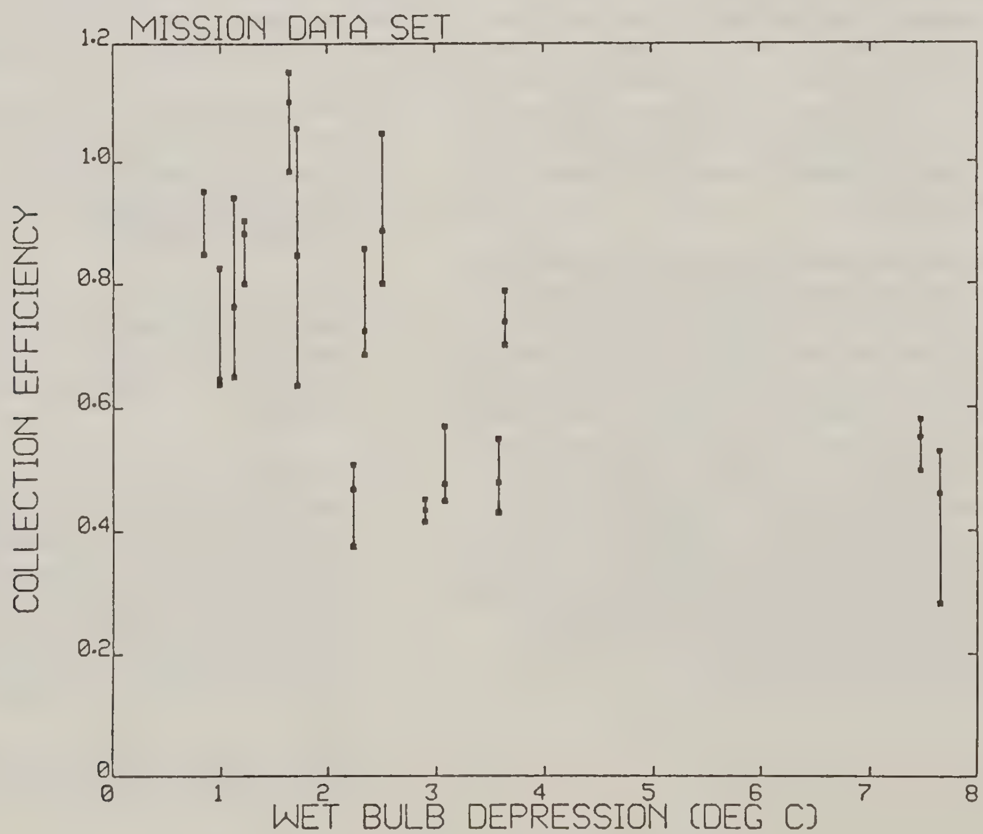

Figure 2. — Collection efficiency for the 15 Mission data sets. Here the squares represent each card row value, with vertical lines connecting each run.

The deposition cards were only 0.15 meters above the surface. At this height the vertical local wind velocity is nearly zero, and a collection efficiency approaching unity would be a good assumption for the larger particles. However, local motion about the cards could sweep smaller particles off or around the cards before impact, leading to lower collection efficiencies. This effect may be seen in Figure 2, where the runs where evaporation was more important (larger wet bulb depression) result in smaller particles near the surface, and therefore smaller collection efficiencies. The trend seen in Figure 2 is correct in that smaller particles would tend to collect less on the elevated cards. The interpretation of experimental data introduced several values above an efficiency of 1, which is an indication of the error associated with this type of measuring procedure.

All of the following data comparisons use the collection efficiencies given in Figure 2. Alternately, we could have chosen a nominal collection efficiency between 0.6 and 0.8 to represent the Mission spray trials. This efficiency would have lead to a 10- to 20-percent change in the magnitude of the measured data results shown in the *AGDISP Model Comparisons*, but would not have changed the shape or location of the measured data relative to the predictions.

The volatility fraction, f, was obtained by using the results of run 6, selected because of its large wet bulb temperature depression. The assumption was made that all particle sizes (for run 6) evaporated as far as the assumed volatility fraction of material on the cards by image analysis referred to as the amount released of 18.2 gal/min divided by the volume fraction of material on the cards by washoff, referred to a tracer amount in the released material, equals 1−f . A simple iterative procedure computed that

(2) $$f = 0.54$$

or that particle sizes would reduce to no less than 0.77 their initial nozzle values. The volatility fraction given by Equation 2 was used with all experimental data. The washoff results helped to scale the data, but they could not be compared directly with AGDISP predictions because they were used to set the collection efficiency.

In practice the larger particle sizes all hit the surface nearly below the aircraft (Figure 3). The effect of drift needed to be considered only with the smaller particle sizes. Note, in Figure 3 the smaller particles are easily trapped within the aircraft vortices. A typical AGDISP input deck is given in Figure 4.

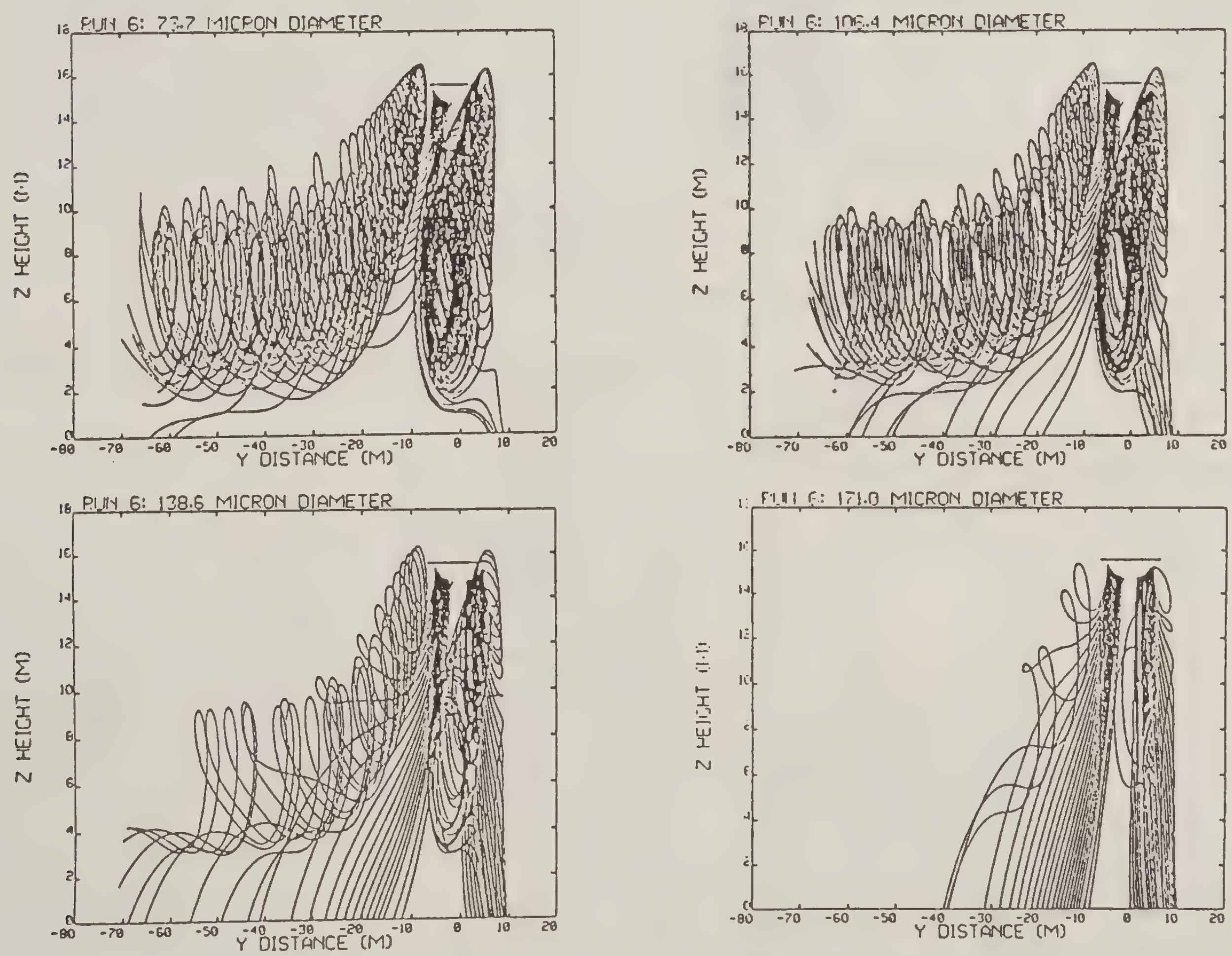

Figure 3. — Particle trajectories for run 6 for the 47 nozzles initialized in the Mission data set. A y distance of 0 is referenced to the aircraft centerline.

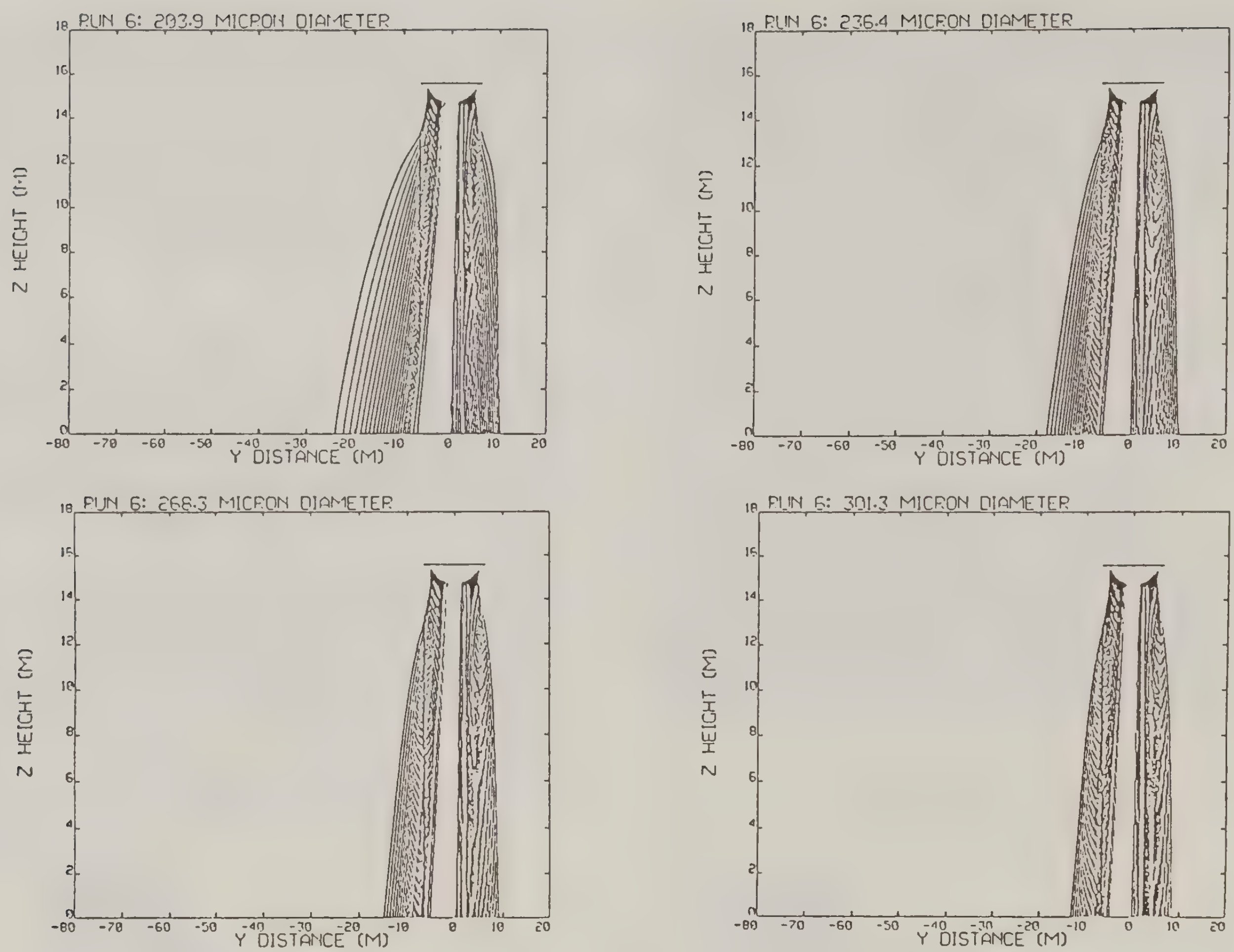

Figure 3. — (Continued)

```
0000  CESSNA 188 AGTRUCK -- 73.7 MICRON DIAMETER -- RUN 6
0010  180.0  2
0011  2000  0  0
0020  2  1  6.37  15.55  51.9  0
0022  16.73
0028  -0.19  10.0  0.0188
0040  0.1  19.05  0.8  2400.0  1.02  -0.4
0050  0  0.237  30.0
0060  -23  -1  0.0  73.7  1.0  1
0061  -5.093  -0.244
0061  -4.940  -0.257
0061  -4.788  -0.295
0061  -4.623  -0.339
0061  -4.470  -0.396
0061  -4.318  -0.422
0061  -4.166  -0.447
0061  -4.007  -0.485
0061  -3.848  -0.523
0061  -3.696  -0.549
0061  -3.543  -0.600
0061  -3.378  -0.625
0061  -3.188  -0.650
0061  -3.035  -0.676
0061  -2.883  -0.695
0061  -2.724  -0.708
0061  -2.572  -0.739
0061  -2.413  -0.752
0061  -2.261  -0.777
0061  -2.108  -0.790
0061  -1.956  -0.822
0061  -1.638  -0.847
0061  -1.334  -0.892
0061   1.334  -0.892
0061   1.499  -0.873
0061   1.651  -0.854
0061   1.803  -0.828
0061   1.962  -0.815
0061   2.273  -0.777
0061   2.426  -0.752
0061   2.584  -0.746
0061   2.743  -0.714
0061   2.896  -0.695
0061   3.048  -0.676
0061   3.200  -0.650
0061   3.397  -0.625
0061   3.556  -0.600
0061   3.708  -0.568
0061   3.861  -0.542
0061   4.013  -0.511
0061   4.166  -0.485
0061   4.318  -0.447
0061   4.477  -0.434
0061   4.636  -0.396
0061   4.788  -0.365
0061   4.934  -0.333
0061   5.105  -0.295
0065  7.47  57.0
```

Figure 4. — AGDISP input deck for the 73.7 micron size particles in run 6 of the Mission data set. Input card explanation may be found in Teske (Ref. 1).

AGDISP Model Comparisons

Of the 21 runs conducted at Mission, 15 were supplied to Continuum Dynamics, Inc. The procedure outlined in the *Data Reduction Algorithm* section of this report was then invoked for each run. The comparisons between prediction and experiment are given in Figures 5 to 19.

In sum, the results demonstrate that AGDISP makes an excellent prediction of the data. Some of the number density predictions (especially runs 1, 11, 12, 15, and 16) are lower than the data, while the volume predictions are consistent with all 15 data sets. In many cases a surprisingly large variance exists between card rows, as evidenced by the vertical lines connecting the ground deposition data. This variance may be attributed to turbulent fluctuations at the Mission test site or inconsistencies in reduction of the raw test data. This variance indicates the difficulty in repeating field test data.

This agreement is present in all particle size classes by examing run 6 (as typical) for volume (Figure 20) and number density (Figure 21). The predictions are consistent with experimental data levels in all eight particle size classes.

Volume fraction deposited is shown in Figure 22. Here the experimental bin sizes have been collected, converted to volume, divided by collection efficiency, and then divided by the nozzle flow rate of 18.2 gal/min. The data trend is correct here, in that higher evaporation rates should evaporate more material, increase drift, and decrease deposition.

If we remain consistent with the Equivalent Gaussian Distribution in AGDISP (*Teske, Ref. 1*), we may define a Figure of Merit (FOM) of our predictions with the Mission data

$$\text{(3)} \quad FOM = 1 - \frac{\int (c_p - c_m)^2 dy}{\int (c_p^{\,2} + c_m^{\,2}) dy} = \frac{2\int c_p c_m dy}{\int (c_p^{\,2} + c_m^{\,2}) dy}$$

where the integrals in Equation 3 are taken along the surface (in the y direction), and c_p and c_m are predicted and measured ground deposition data, respectively. It may be seen by Equation 3 that if the predicted deposition everywhere matches the measured deposition, $c_p = c_m$ and FOM = 1. If the predicted deposition is everywhere zero when the measured deposition is nonzero, and visa versa, then FOM = 0. Applying Equation 3 to the Mission data set yields the results shown in Figure 23. A mean value of 0.74 represents the average predictions of the Mission data set.

The total predicted and measured deposition levels are plotted in Figure 24.

The real worth of the AGDISP predictions is in whether they can accurately predict the swath width and swath mean position. Following the technique discussed in Barry, *et. al.* (*Ref. 16*), we selected four deposition levels for swath comparisons with the Mission data set. With both the data and the predictions, we determined the swath mean position and swath width.

Figures 25 to 28 show the predicted and measured swath means and widths for the four deposition levels selected. Note that the swath mean is quite accurately predicted, and the swath width somewhat less so.

With the evaporation model discussed previously, we were able to determine the corrected bins for each Mission run as a function of wet bulb temperature depression. It seems possible, then, to sum the number density and volume in each bin and normalize these results for all 15 Mission runs. A comparison may then be made with the Yates and Steinke particle size classes. Such a comparison is shown in Figure 29. The normalization removes the smallest and largest particle sizes since these were not predicted by AGDISP. Note that the ground deposition data gives the same shape as the nozzle sizes developed by Yates and Steinke. A re-examination of Mission run 6 with these new volume percentages showed little difference from the results given in Figure 8.

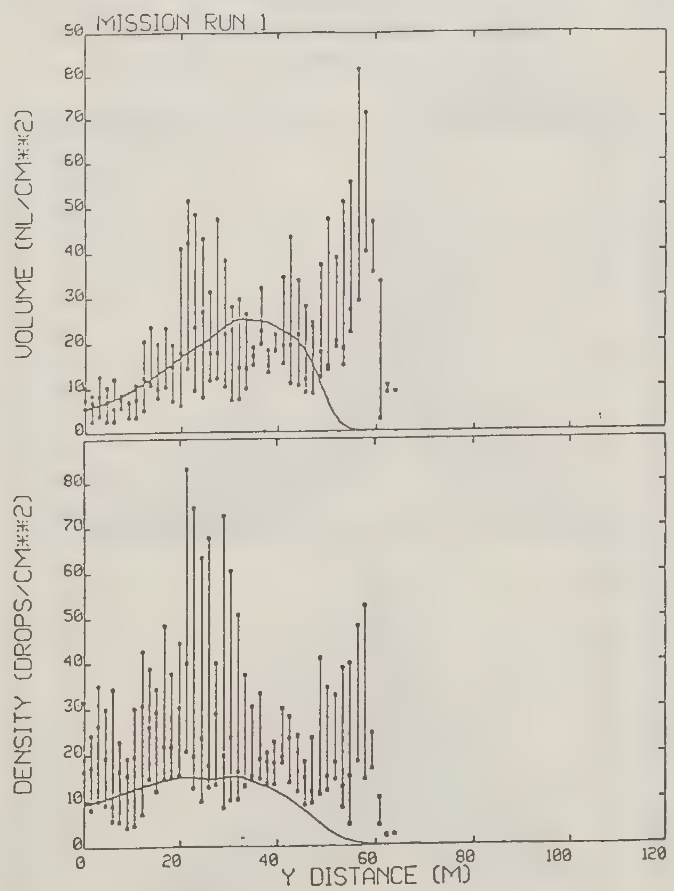

Figure 5. — Comparisons of AGDISP prediction (———) with Mission run 1 card row data (squares connected by vertical lines). The top curve is volume; the bottom curve is number density. A, y, distance of 0 refers to the farthest left card position.

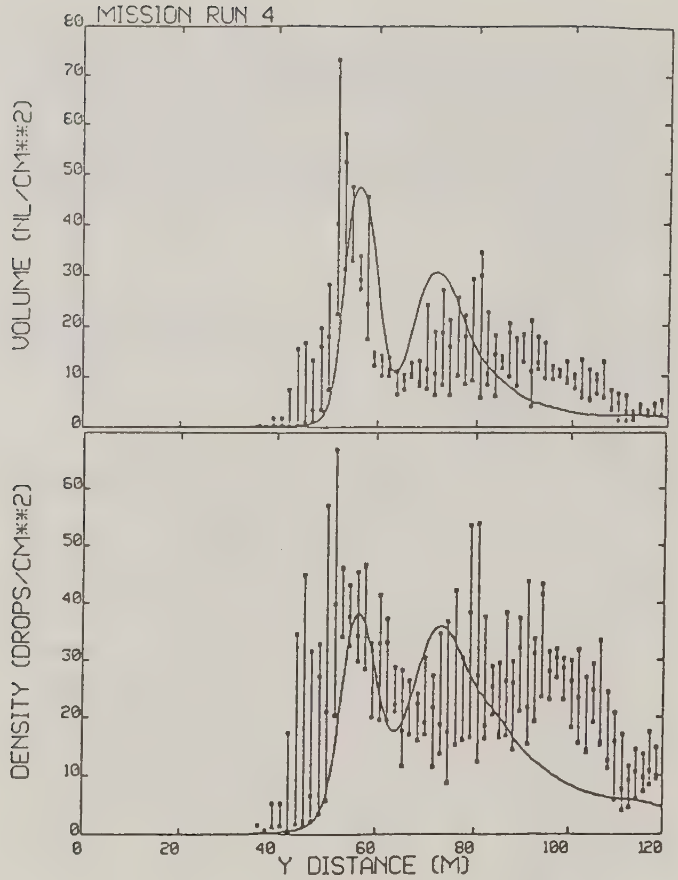

Figure 6. — Comparisons for Mission run 4.

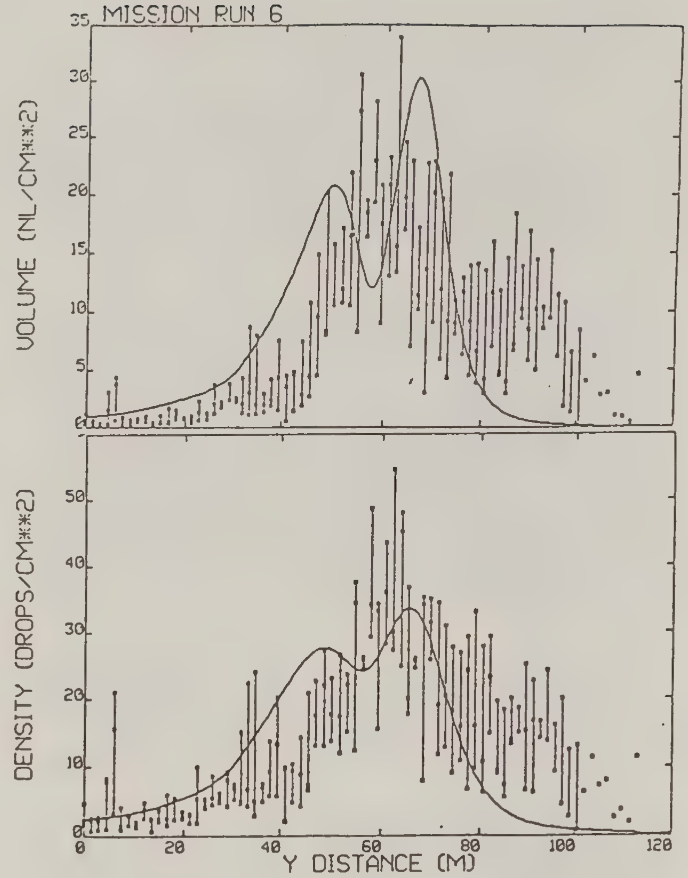

Figure 8. — Comparisons for Mission run 6.

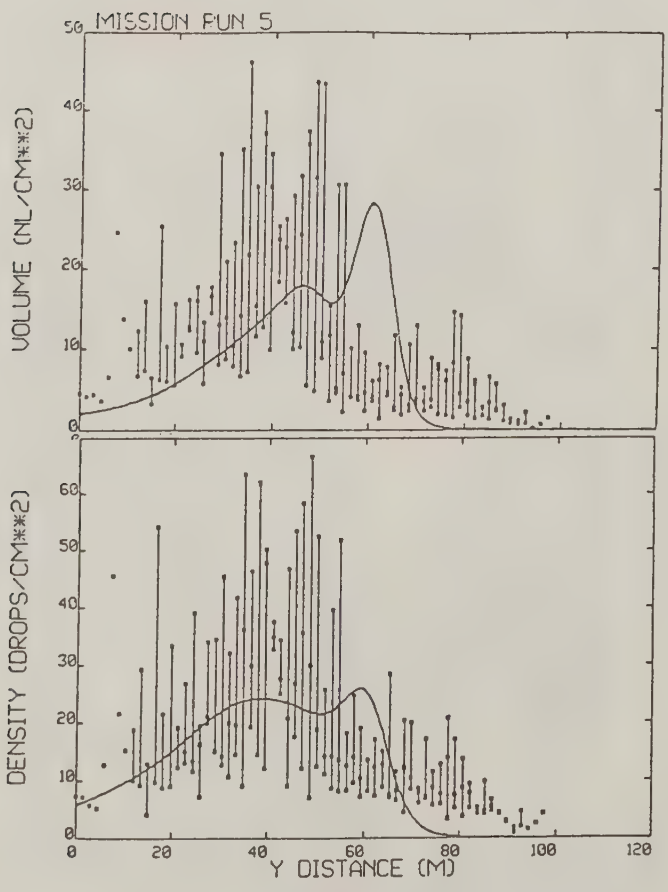

Figure 7. — Comparisons for Mission run 5.

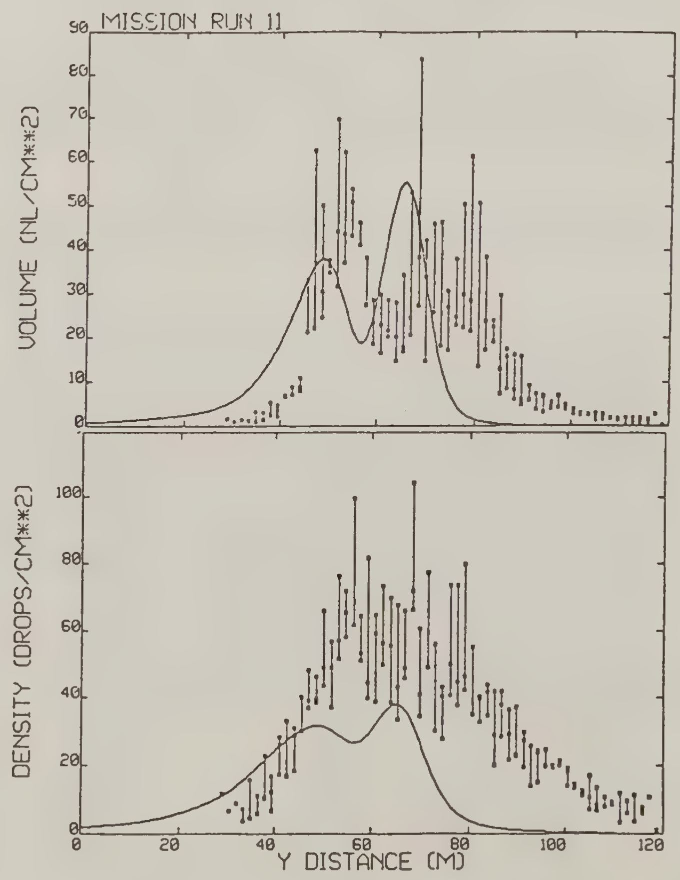

Figure 9. — Comparisons for Mission run 11.

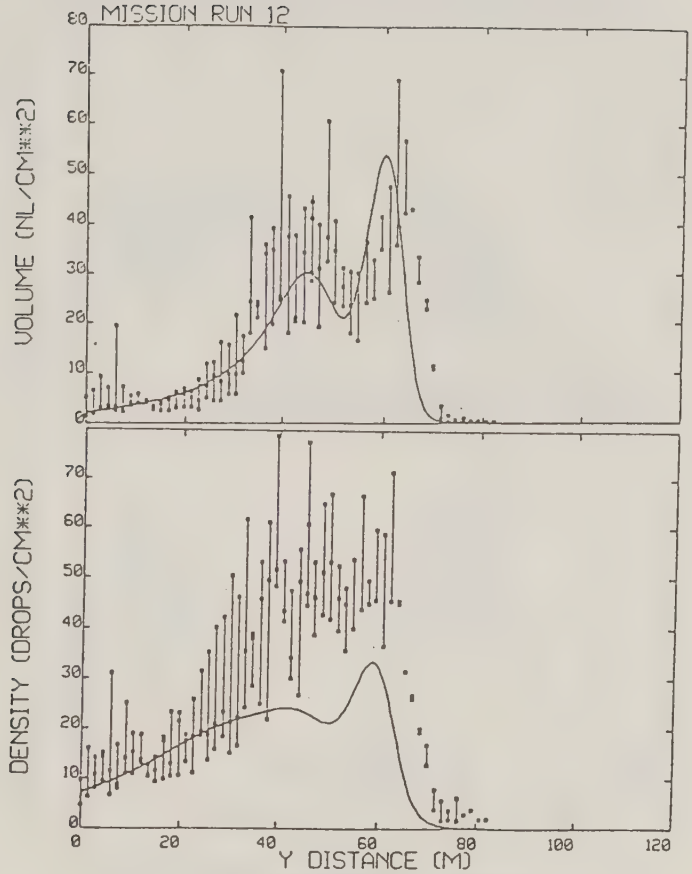

Figure 10. — Comparisons for Mission run 12.

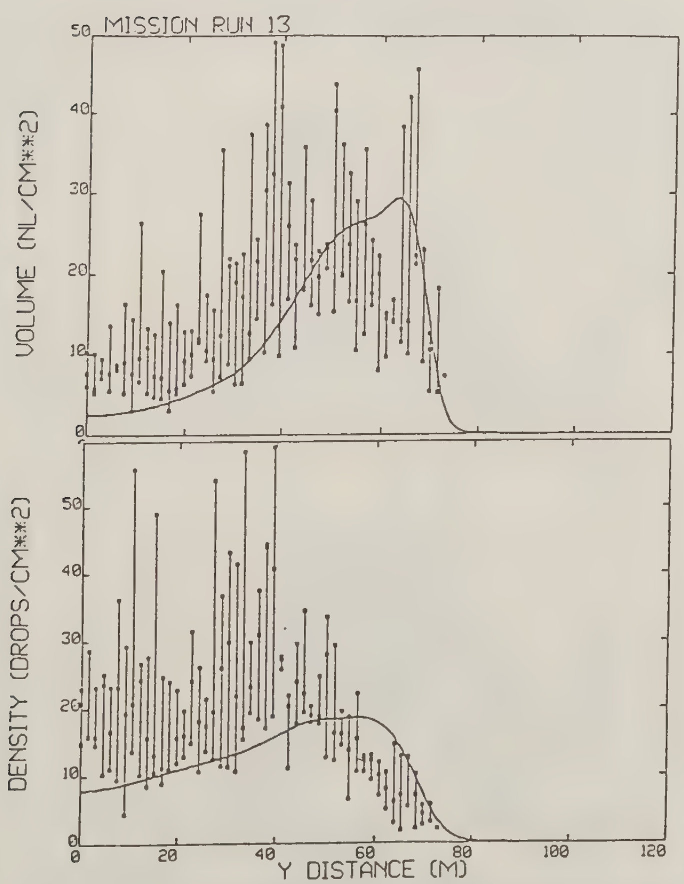

Figure 11. — Comparisons for Mission run 13.

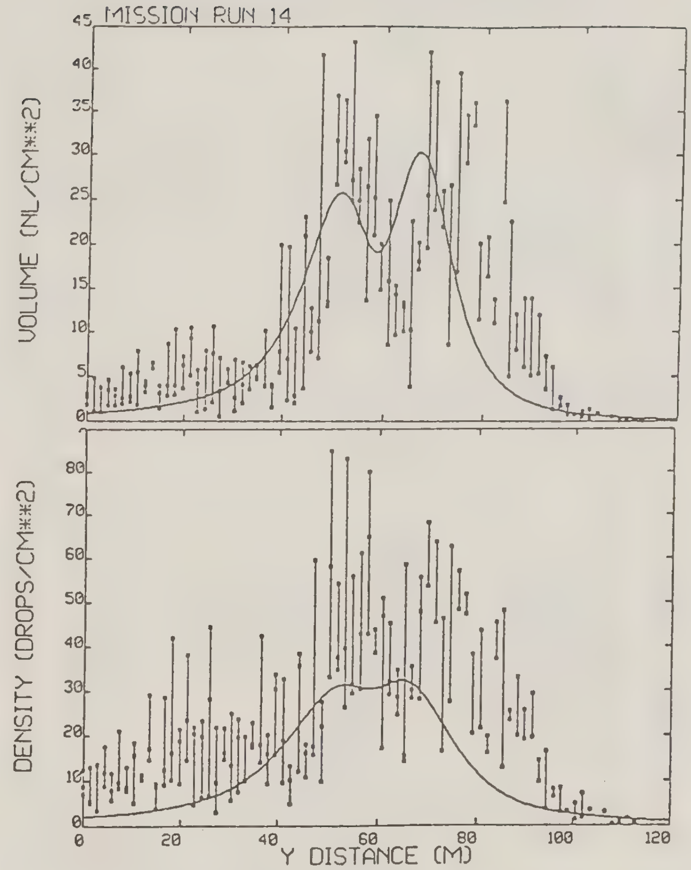

Figure 12. — Comparisons for Mission Run 14.

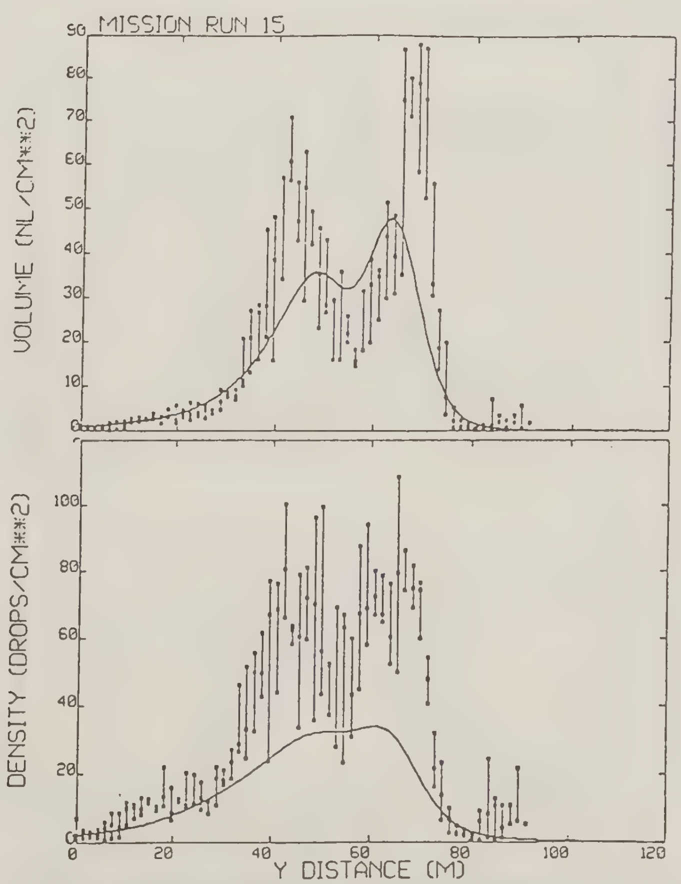

Figure 13. — Comparisons for Mission run 15.

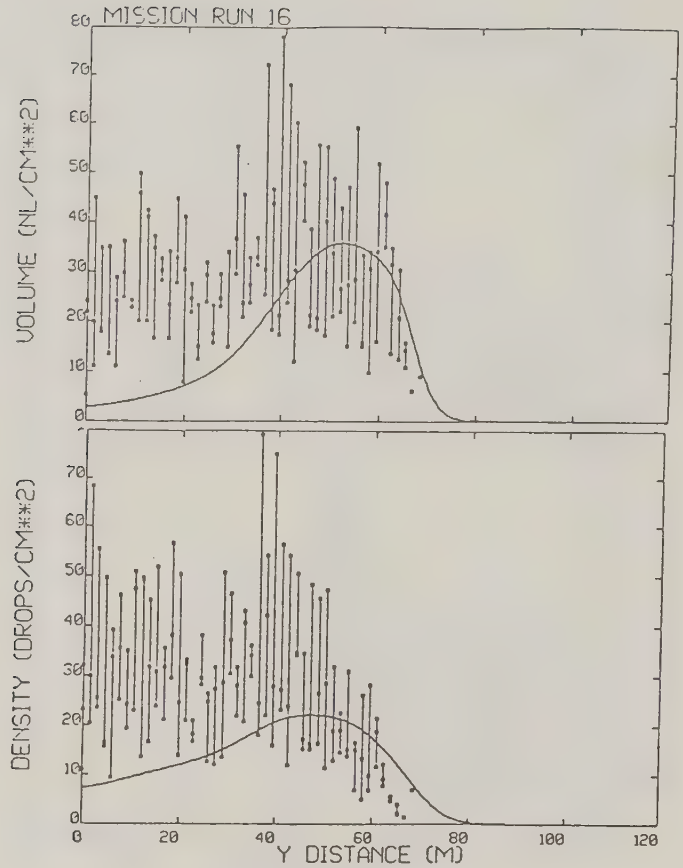

Figure 14. — Comparisons for Mission run 16.

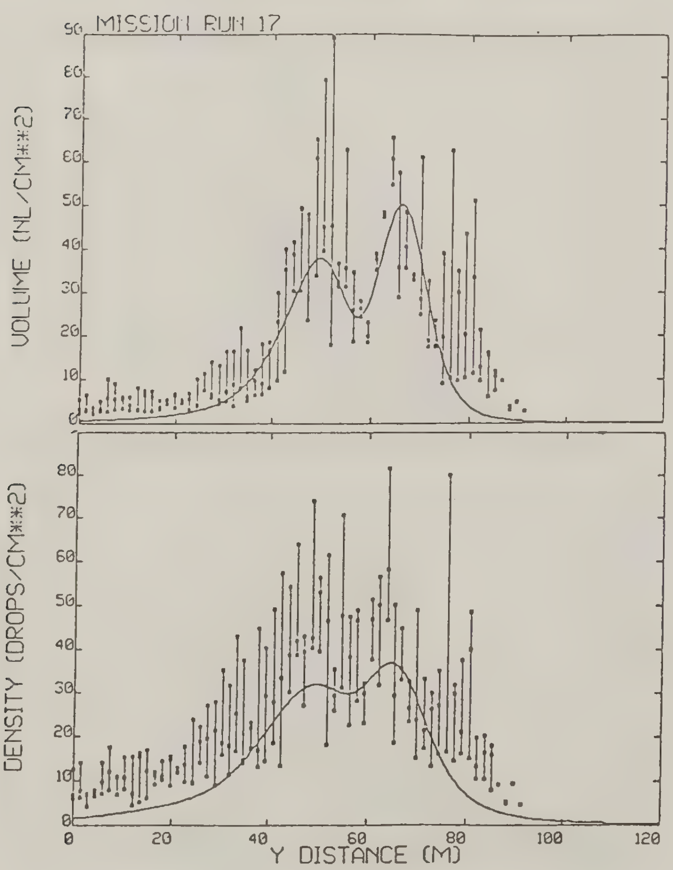

Figure 15. — Comparisons for Mission run 17.

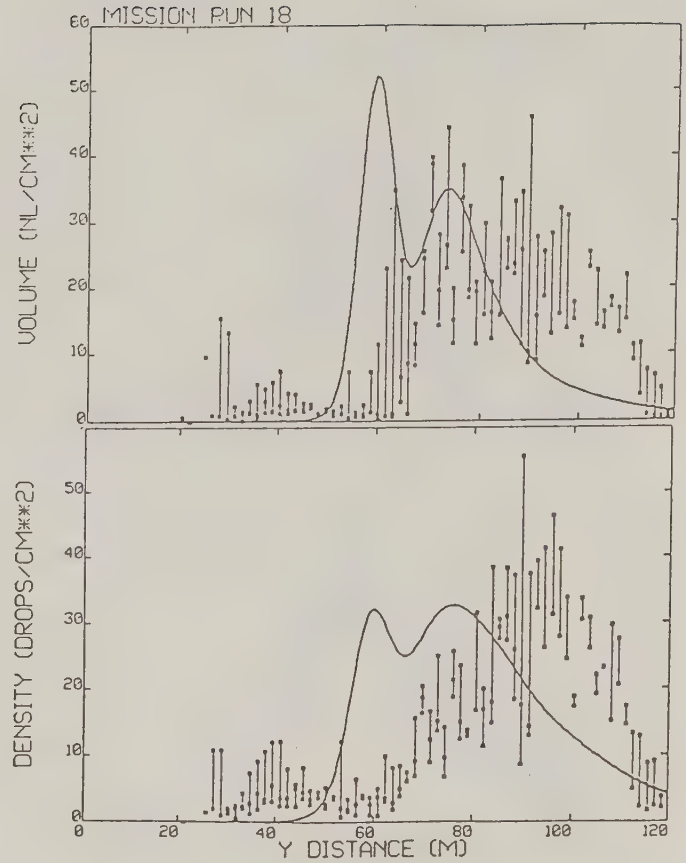

Figure 16. — Comparisons for Mission run 18.

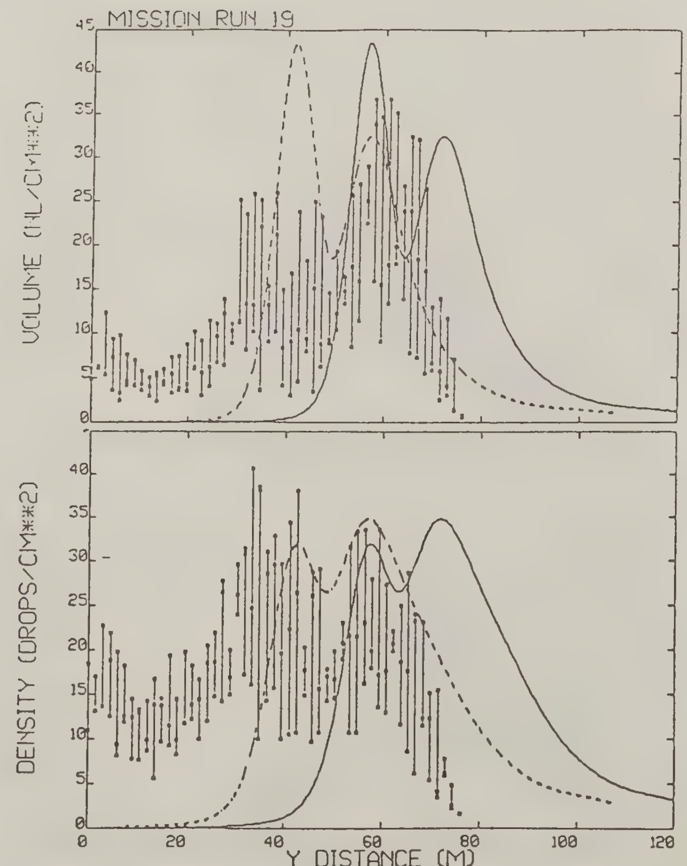

Figure 17. — Comparisons for Mission run 19. The dashed curve illustrates a shift in the prediction of 15 meters to the left.

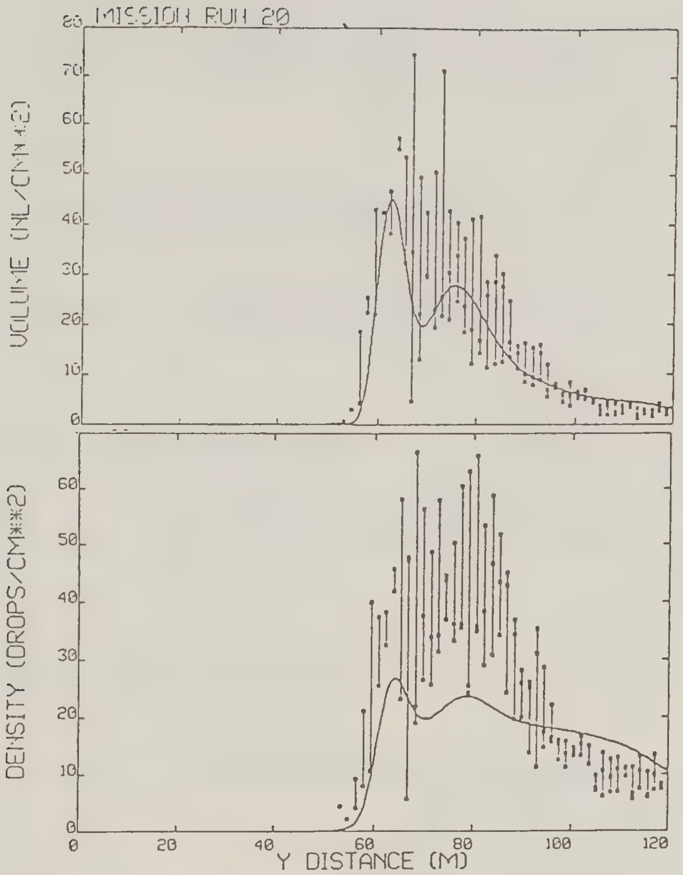

Figure 18. — Comparison for Mission run 20.

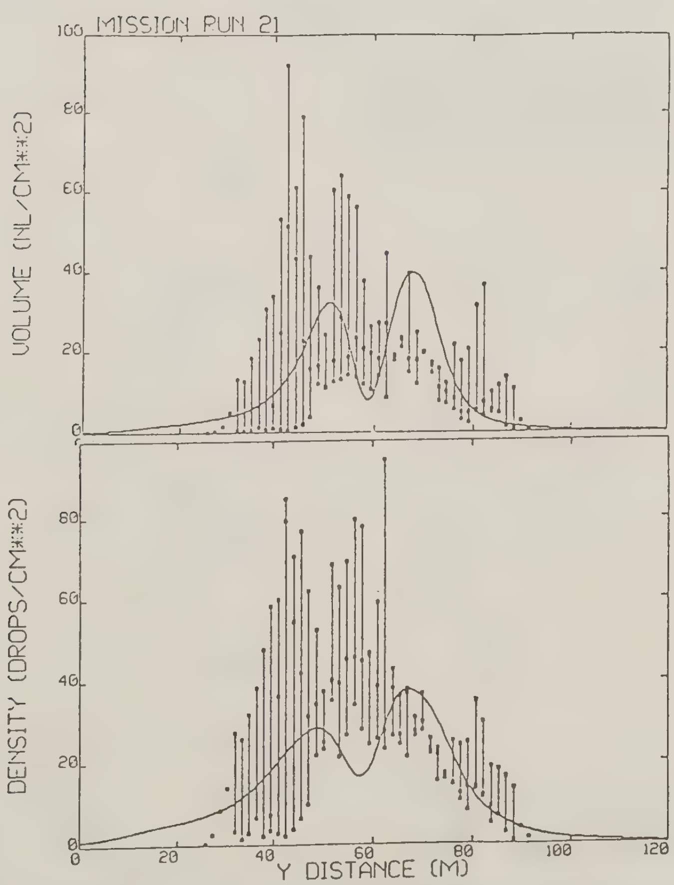

Figure 19. — Comparisons for Mission run 21.

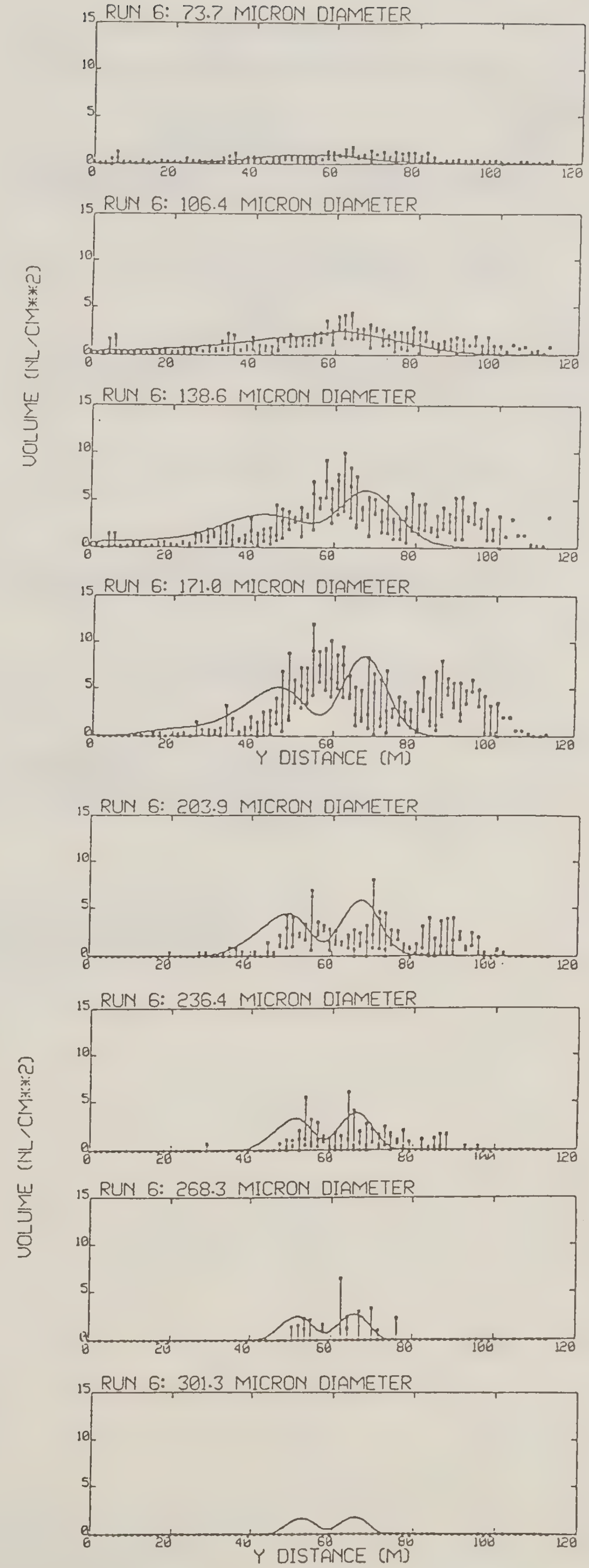

Figure 20. — Volume comparisons of AGDISP prediction (———) with Mission run 6 card row data (squares connected by vertical lines) for the eight particles size classes.

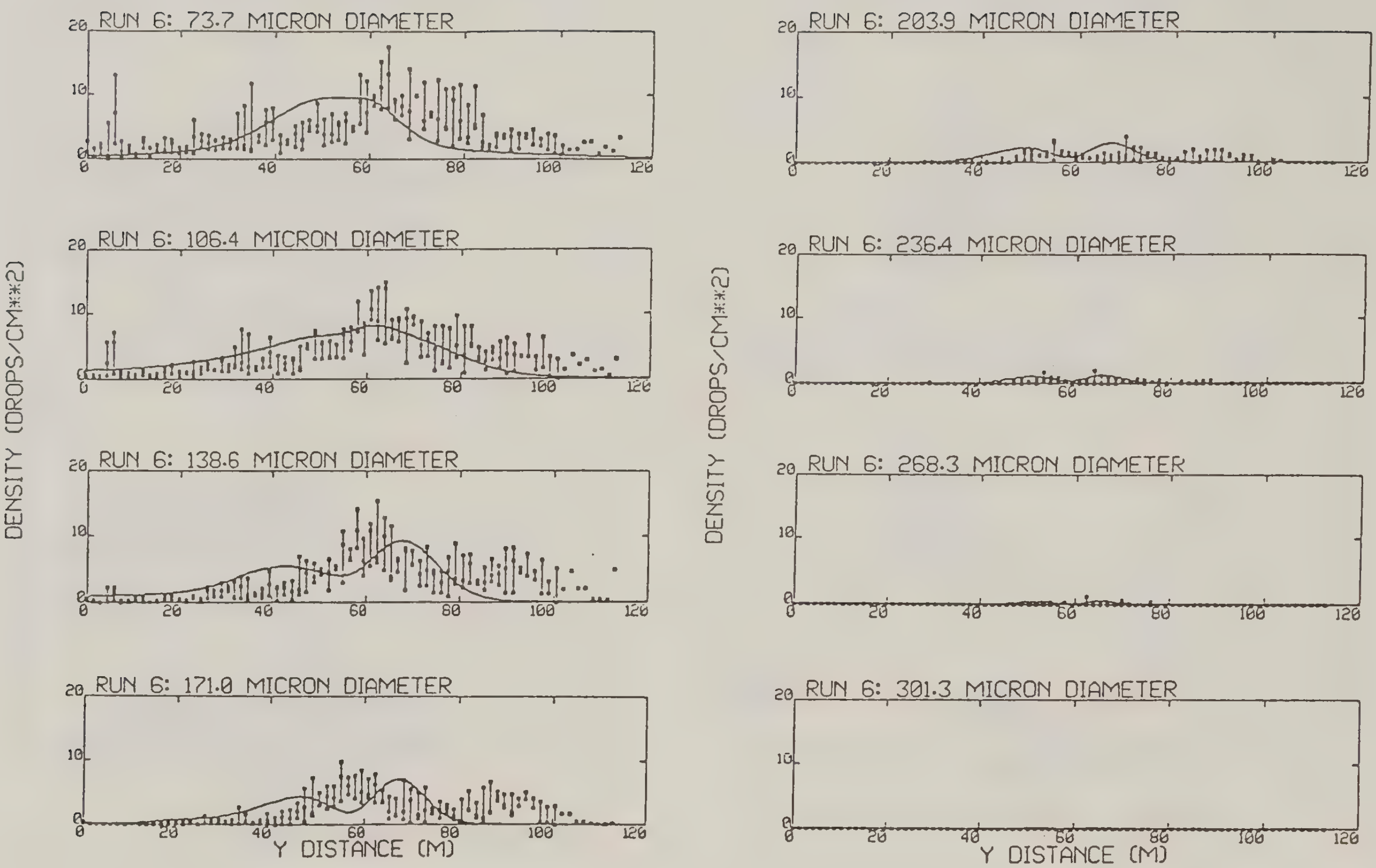

Figure 21. — Number density comparisons of AGDISP prediction (———) with Mission run 6 card row data (squares connected by vertical lines) for the eight particle size classes.

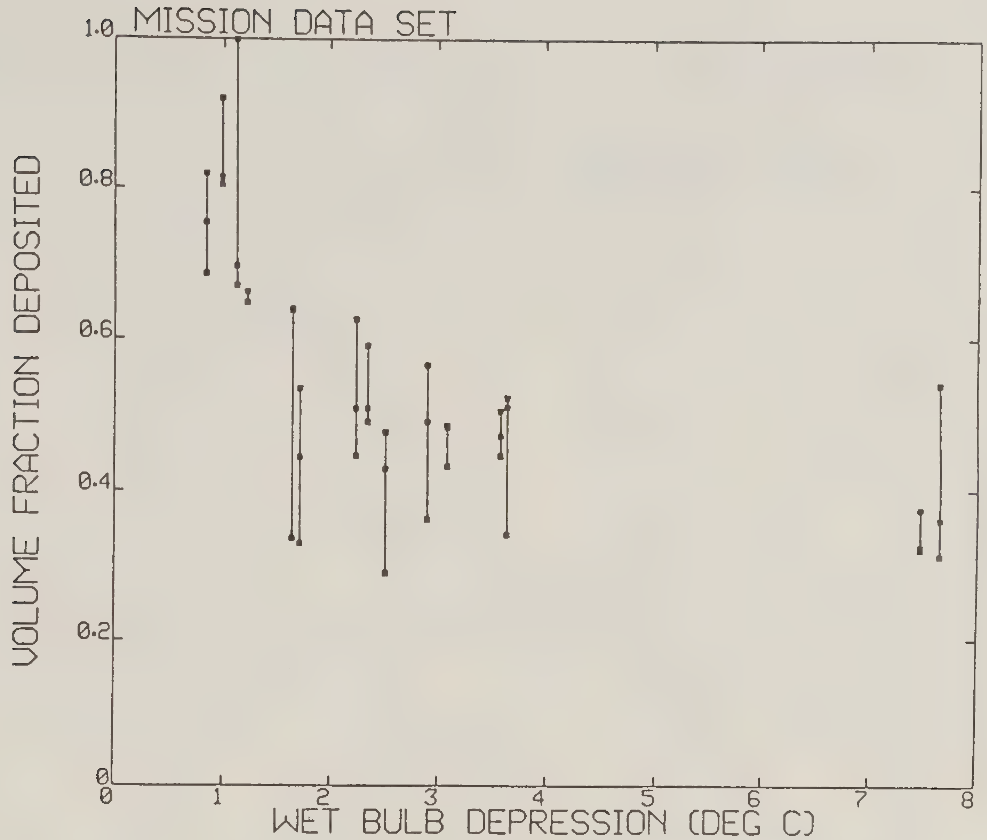

Figure 22. — Volume fraction deposited for the 15 Mission data sets. The squares represent each card row value, with vertical lines connecting each run.

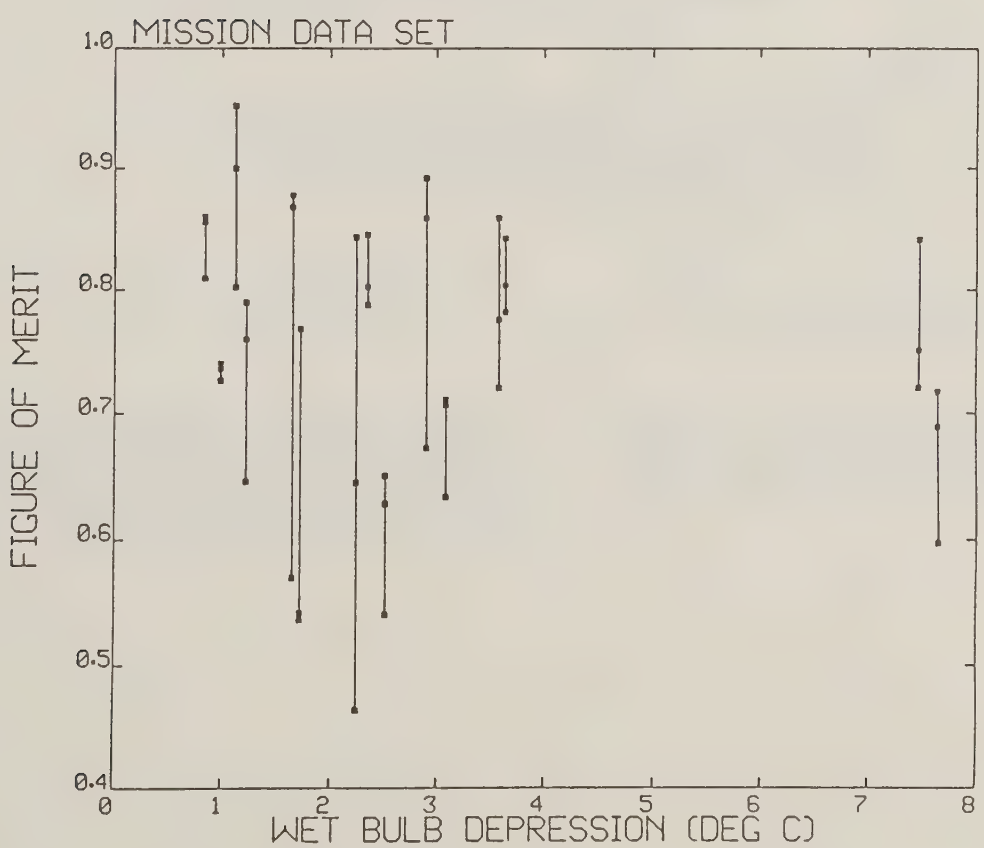

Figure 23. — Figure-of-merit measure of the AGDISP predictions for the 15 Mission data sets. The squares represent each card row value, with vertical lines connecting each run.

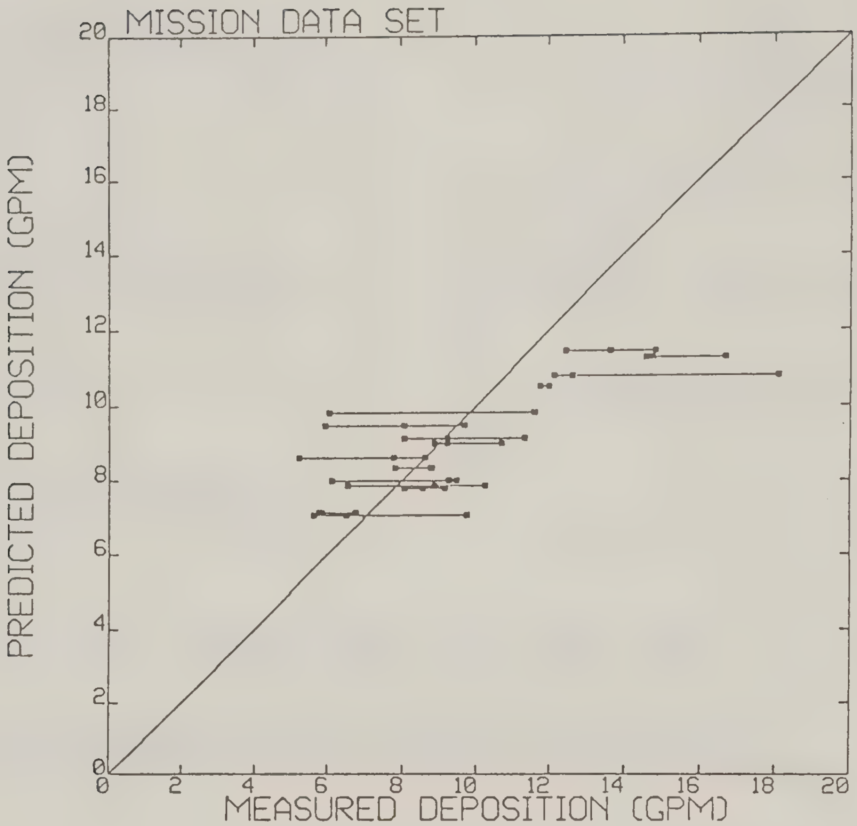

Figure 24. — Total predicted deposition versus measured deposition on the card rows for the 15 Mission data sets. The squares represent each card row value, with horizontal lines connecting each run. The correlation coefficient is 0.79 with a standard deviation from a straight line fit of 2.23 gal/min.

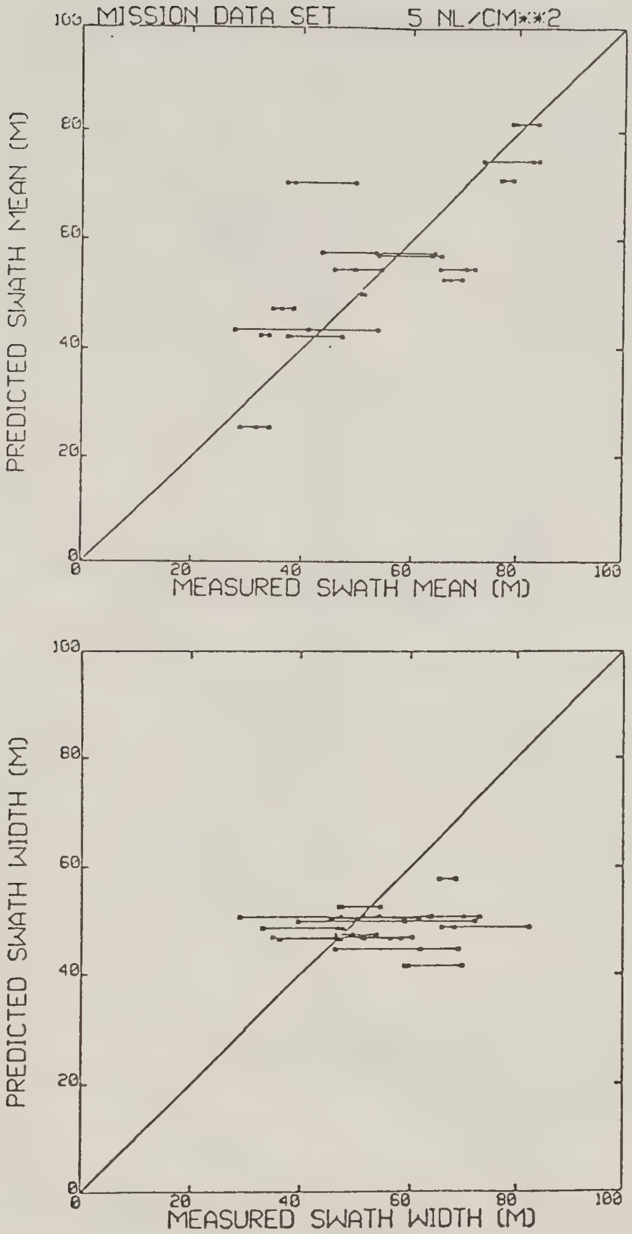

Figure 25. — Predicted and measured swath mean (top) and width (bottom) for all 15 Mission data sets for a deposition level of 5 nl/cm². The squares represent each card row value, with horizontal lines connecting each run. The swath mean correlation is 0.76 with a standard deviation from a straight line fit of 11.34 meters. The swath width correlation is 0.10 with a standard deviation of 13.53 meters.

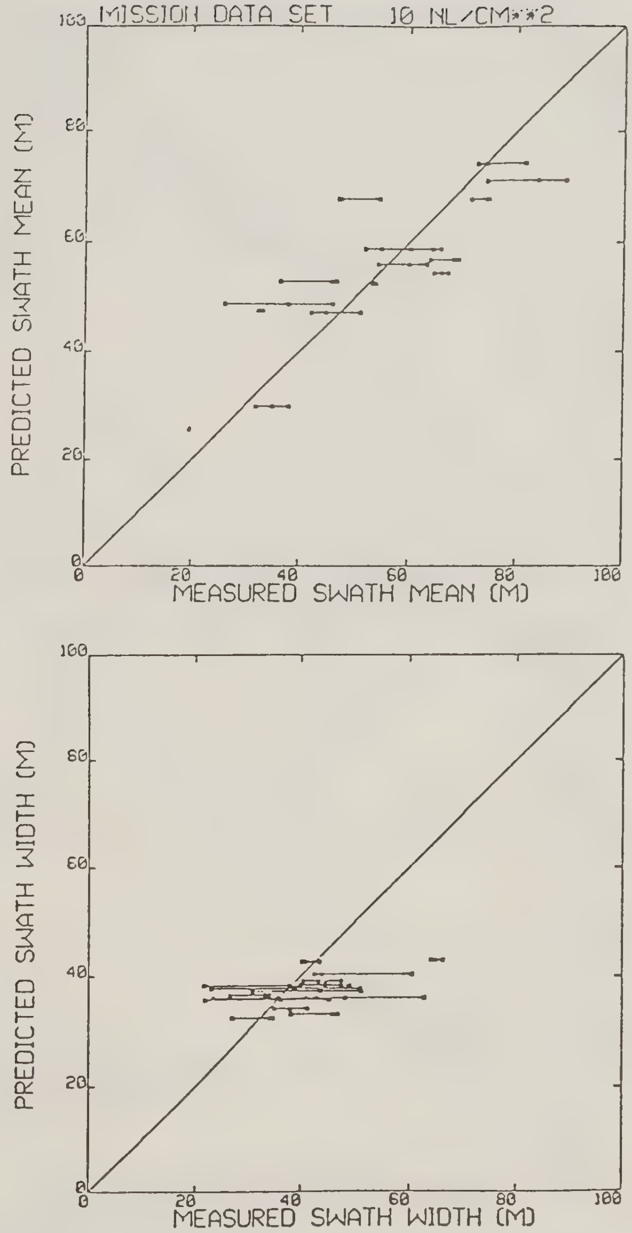

Figure 26. — Predicted measured swath mean (top) and width (bottom) for a deposition level of 10 nl/cm². The mean correlation is 0.77 and standard deviation is 9.96 meters. The width correlation is 0.46 and standard deviation is 10.76 meters.

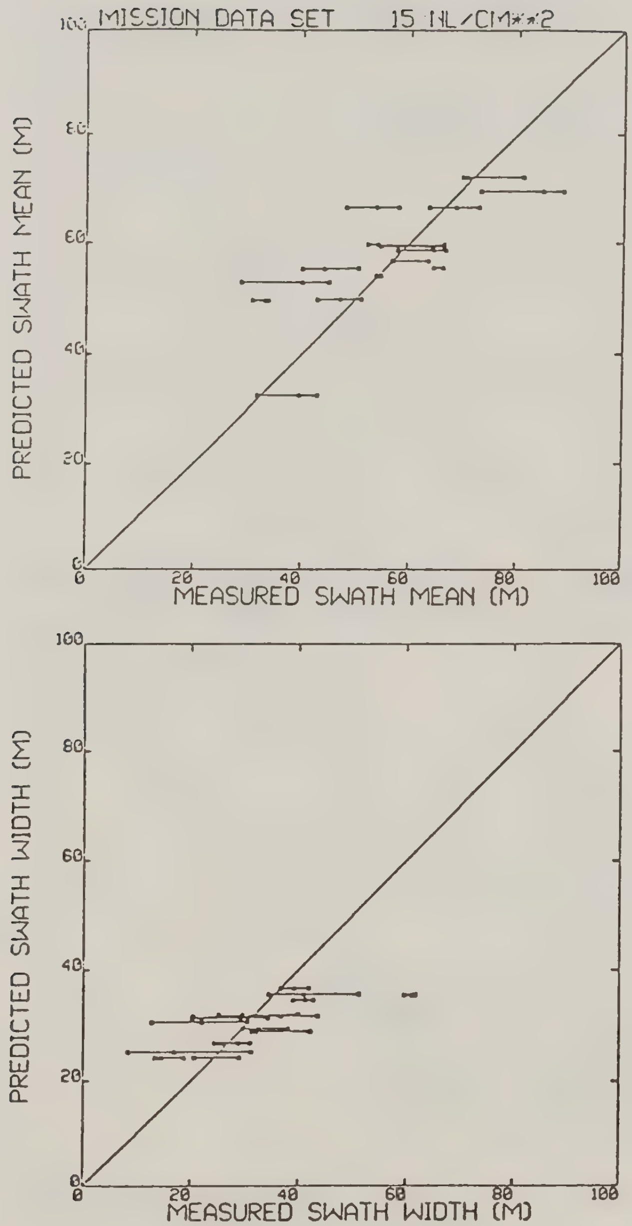

Figure 27. — Predicted and measured swath mean (top) and width (bottom) for a deposition level of 15 nl/cm². The mean correlation is 0.74 and standard deviation is 9.75 meters. The width correlation is 0.72 and standard deviation is 9.80 meters.

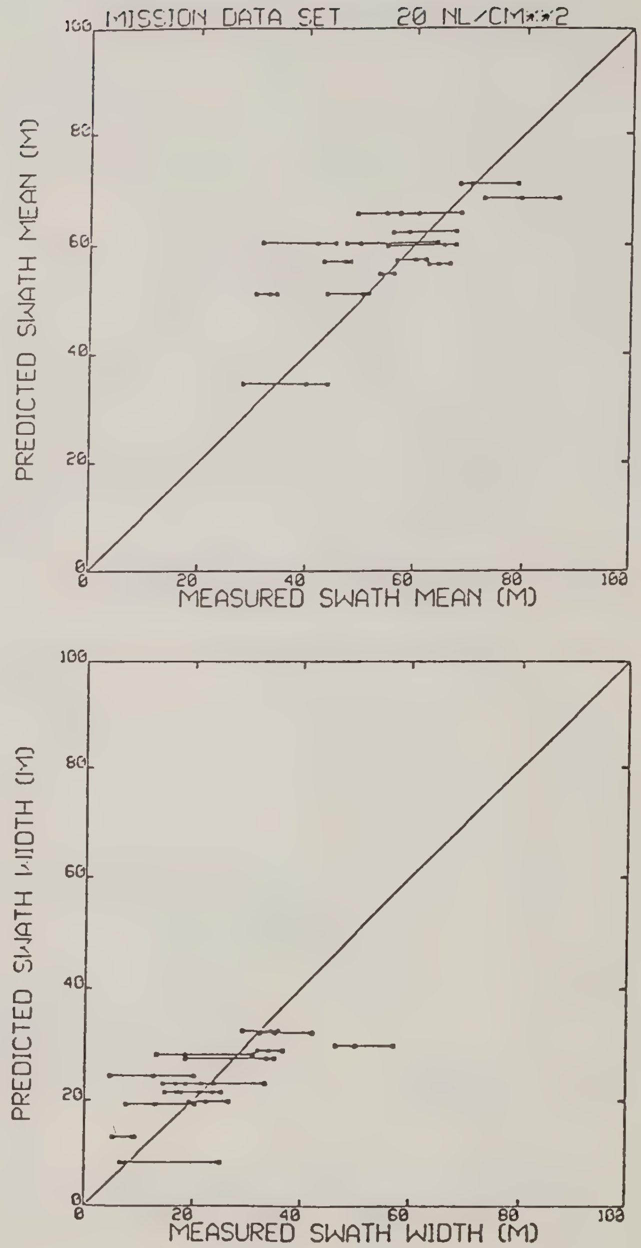

Figure 28. — Predicted and measured swath mean (top) and width (bottom) for a deposition level of 20 nl/cm². The mean correlation is 0.67 and standard deviation is 10.26 meters. The width correlation is 0.68 and standard deviation is 8.98 meters.

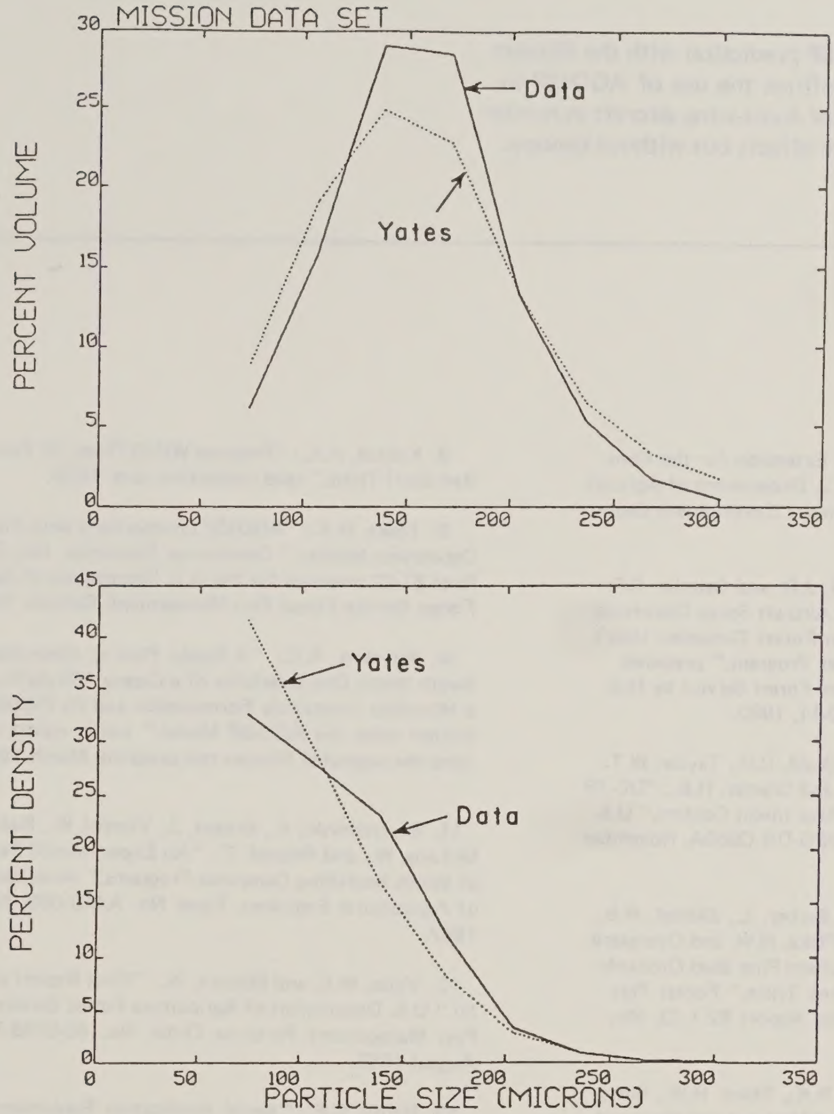

Figure 29. — A comparison of volume and number density normalized across the eight particle size classes, from Yates and Steinke (Ref. 12) and developed from the ground deposition data.

Conclusions

This report documents AGDISP prediction with the Mission data set. This comparison confirms the use of AGDISP in making accurate predictions for fixed-wing aircraft in moderate crosswind with evaporative effects but without canopy.

References

1. Teske, M.E.: "User Manual Extension for the Computer Code AGDISP Mod 4.0," U.S. Department of Agriculture Forest Service Missoula Equipment Development Center Report 8634-2809, April 1986.

2. Dumbauld, R.K., Bjorklund, J.R. and Saterlie, S.F.: "Computer Models for Predicting Aircraft Spray Dispersion and Deposition Above and Within Forest Canopies: User's Manual for the FSCBG Computer Program," prepared for U.S. Department of Agriculture Forest Service by H.E. Cramer Company, Inc., Report 80-11, 1980.

3. Boyle, D.G., Barry, J.W., Eckard, C.O., Taylor, W.T., McIntyre, W.C., Dumbauld, R.K. and Cramer, H.E.: "DC-7B Aircraft Spray System for Large-Area Insect Control," U.S. Army Dugway Proving Grounds DPG-DR-C980A, November 1975.

4. Barry, J.W., Kenney, P.A., Barber, L., Ekblad, R.B., Dumbauld, R.K., Rafferty, J.E., Flake, H.W. and Overgaard, N.A.: "Aerial Application to Southern Pine Seed Orchards: Data Report of the Withlacoochee Trials," Forest Pest Management Asheville Field Office Report 82-1-23, May 1982.

5. Rafferty, J.E., Dumbauld, R.K., Flake, H.W., Barry, J.W. and Wong, J.: "Comparison of Modeled and Measured Deposition for the Withlacoochee Spray Trials," U.S. Department of Agriculture Forest Service Forest Pest Management Methods Applications Group Report 81-3, June 1981.

6. Morris, D.J., Croom, C.C., van Dam, C.P. and Holmes, B.J.: "An Experimental and Theoretical Investigation of Deposition Patterns from an Agricultural Airplane, "NASA Technical Paper 2348, September 1984.

7. Keetch, A.K.: "Program WIND Phase I Test Results: Chico Trials," card deposition data, 1985.

8. Keetch, A.K.: "Program WIND Phase III Test Results: Red Bluff Trials," card deposition data, 1986.

9. Teske, M.E.: "AGDISP Comparisons with Four Field Deposition Studies," Continuum Dynamics, Inc. Technical Note 87-02 prepared for the U.S. Department of Agriculture Forest Service Forest Pest Management, October 1987.

10. Reardon, R.C.: "A Study Plan to Determine the Swath Width Characteristics of a Cessna 188 AgTruck using a Microbial Insecticide Formulation and its Possible Prediction using the AGDISP Model," Letter report summarizing the suggested Mission test program, March 1987.

11. Mierzejewski, K., Bryant, J., Yendol, W., Reardon, R., McLane, W., and Roland, T.: "An Experimental Evaluation of Swath Modelling Computer Programs," American Society of Agricultural Engineers, Paper No. AA87-005, November 1987.

12. Yates, W.E. and Steinke, W.: "Final Report on Mission III," U.S. Department of Agriculture Forest Service Forest Pest Management Purchase Order No. 40-9158-7-0722, August 1987.

13. Hardy, C.E.: "Aerial Application Equipment," U.S. Department of Agriculture Forest Service Missoula Equipment Development Center Report 8734-2804, April 1987.

14. Weast, R.C. (ed): CRC Handbook of Chemistry and Physics, 62nd edition, page E-43, 1981.

15. Herdan, G: Small Particle Statistics, Buttersworths, London, page 33, 1960.

16. Barry, J., Ekblad, R., Markin, G., and Trostle, G.: "Methods for Sampling and Assesssing Deposits of Insecticidal Sprays Released over Forests," USDA Technical Bulletin No. 1596, 1978.

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